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Respiratory Morbidity in Relationship to Farm Characteristics in Swine Confinement Work: Possible Preventive Measures

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Swine confinement farming is associated with an increased risk of respiratory morbidity. Adverse health effects have been shown in association with levels of dust, endotoxins, and ammonia. This study was conducted to evaluate characteristics of confinement farms associated with respiratory morbidity in order to establish priorities for preventive measures. A questionnaire on symptoms and farm characteristics was completed by 1,432 male swine confinement farmers. Of these, 200 with and 200 without chronic respiratory symptoms were randomly selected for lung function testing. A significantly increased risk for chronic respiratory symptoms was shown if farmers used wood-shavings as bedding (prevalent odds ratio [POR] 2.2), used disinfectants (POR 1.7), used natural ventilation (POR 2.6), had floor types other than slatted or half-slatted (POR 2.1), or used a mechanical feeding system (POR 1.4). Lung function (FEV$_1$) was significantly lower with increasing numbers of years worked (51 ml/10 years), with smaller numbers of pigs (8.5 ml/100 pigs), and when the air outlet of the ventilation system was via the pit (248 ml). To decrease the risk of respiratory morbidity the following preventive measures are proposed: discouragement of the use of disinfectants and of wood-shavings as bedding, and promotion of the use of mechanical ventilation systems. © *1996 Wiley-Liss, Inc.*

KEY WORDS: ***chronic bronchitis, asthma, swine confinement workers, pig farmers, pulmonary function, occupational hazards, prevention, endotoxin***

INTRODUCTION

During the past 20 years a number of studies have shown that swine confinement farming is associated with respiratory health risks for the farmer. Especially the prevalence of chronic bronchitis is high among swine farmers [Rylander et al., 1989; Donham, 1990]. Evidence of lung-function decrements is conflicting. Some authors reported mild obstructive changes (<10% lower than reference) [Brouwer et al., 1986; Cormier et al., 1991; Zuskin et al., 1992], whereas others could not confirm these findings [Haglind and Rylander, 1987; Holness et al., 1987; Dosman et al., 1988]. Environmental factors most convincingly associated with respiratory morbidity in swine farmers are endotoxins [Donham et al., 1989; Heederik et al., 1991; Zejda et al., 1994] and to a lesser extent ammonia [Donham et al., 1995]. There are practically no studies on the associations between respiratory morbidity and elements of work in confinement units that are informative for preventive measures. However, Bongers et al. [1987] found lower lung-function values in workers employed in finishing buildings with fully slatted floors, an automatic feeding system, or natural ventilation.

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This study was conducted to identify and evaluate farm characteristics that are associated with the development of respiratory morbidity, for which control measures could be developed. We assumed that farm characteristics determine airborne contaminant levels. Exposure to these contaminants leads to health effects such as bronchial hyperreactivity, obstructive lung-function changes, and respiratory symptoms. The present analysis is part of a large study with a questionnaire survey among 1,504 swine confinement farmers, measurements of airborne contaminants on 198 farms, and measurements of spirometric parameters and bronchial hyperreactivity among 398 and 196 farmers, respectively. The purpose of this analysis was to investigate associations between characteristics of swine farms, chronic respiratory symptoms, and spirometric variables.

SUBJECTS AND METHODS

Questionnaire

A questionnaire was mailed to 2,433 male owners of swine confinement operations in the Southern Netherlands. Addresses and data on farm size for all pig farms in the region were obtained from regional farm organizations. Questionnaires were sent to a random sample of all farms with at least 70 sows, or at least 500 pigs or a combination of at least 50 sows and 300 pigs. In this way, a representative sample of all farmers working primarily in swine production was obtained. The questionnaire contained questions on chronic respiratory symptoms, adapted from a shortened version for self-administering [Heederik et al., 1991] of the British Medical Research Council (BMRC)/ European Community for Coal and Steel (ECCS) questionnaire [1966]; other respiratory symptoms, including symptoms immediately and 4–8 hr after work, symptoms of pulmonary hyperreactivity, and history of atopy during childhood or among relatives; personal characteristics, including age, smoking habits, work history, and sick-leave history; and characteristics and methods of farm operation. A number of extensive questions were designed for this part of the study on the basis of earlier studies [Bongers et al., 1987; Attwood et al., 1987] and of recently conducted walk-through-surveys in swine confinement farms (Table I).

Lung Function

Four hundred of the participating farmers were invited for medical testing, including spirometry: 200 randomly selected cases (farmers with chronic respiratory symptoms) and 200 randomly selected non-cases (without symptoms). Baseline spirometry was actually performed by 398 of them with a Vicatest dry-seal spirometer, according to European Respiratory Society (ERS) standards. Values of forced vital capacity (FVC), forced expiratory volume in 1 sec (FEV_1), maximum expiratory flow when 75% of the FVC remains in the lung (MEF75), MEF50, MEF25, and maximal mid-expiratory flow (MMEF) were measured. Lung-function values were expressed as percentage of reference values [Quanjer, 1993].

ANALYSIS

Computations were completed with the aid of a statistical package for personal computers (Statistix©; Analytical Software, Tallahassee, FL).

Participants were classified as cases when they showed one or more of six chronic respiratory symptoms (cough, phlegm, shortness of breath, wheezing, frequent wheezing, asthma). In the analysis, the swine farmers chosen as referents ($n = 576$) were free of any of these six chronic respiratory symptoms and of 28 non-lasting respiratory symptoms occurring immediately or 4–8 hours after work. The questionnaire contained items on various characteristics of farms and confinement units (Table I). For each of the relevant characteristics, participants were asked whether these characteristics were actually present, divided into five separate components of swine production (farrowing, pigs from farrowing to 25 kg, weaned piglets, non-gravid and pregnant sows, and growing and finishing pigs). A farmer was classified as either "exposed" or "non-exposed" to one or another characteristic on the basis of regular contact with such characteristic as was prevalent in his particular type of operation. In case a farmer had more than one type of operation, we used only information on the type in which he spent most of his time. In this way, dichotomous or nominal variables for exposure to farm characteristics were obtained for each farmer. For the characteristics tested, a priori hypotheses were available as to which aspect should be associated with the larger number of symptoms. Therefore, no correction for multiple comparisons was performed. As expected, age and smoking were important confounders of the associations between chronic symptoms and farm characteristics. Age and smoking habits were controlled for in each model: age was added in the models as a continuous variable; smoking was dichotomized as current smokers and non-smokers. When analysis was performed with smoking defined by the number of pack-years (not shown), this did not alter the results. Therefore, the simpler, dichotomized method was preferred.

A history of childhood atopy was considered a potential confounder and was strongly related to chronic symptoms. However, correction for childhood atopy in the models did not appreciably impinge upon the role played by farm characteristics on the prevalence of symptoms for any one variable (never by more than 0.1). Therefore, childhood atopy was not included in the final models.

Statistical significance of associations between farm characteristics and symptoms was first tested with chi-

TABLE I. Distribution of Farm Characteristics and Univariate Associations Between Farm Characteristics and the Prevalence of One or More Chronic Respiratory Symptoms, Corrected for Age and Smoking: The Netherlands, 1990

Characteristic	n	%[a]	POR[b]	(95% CI)
Type of operation				
Breeding	561	41		
Fattening	197	14	1.2	(0.8–1.8)
Both	620	45	1.1	(0.8–1.5)
Number of pig houses				
1 or 2	544	40		
>2	823	60	1.6	(1.2–2.0)
Number of pigs (including sows and piglets)				
≤560	690	50		
>560	686	50	1.2	(0.9–1.5)
Number of hours worked in the units per week				
≤40	438	32		
>40	914	68	1.4	(1.0–1.8)
Number of years in swine farming				
≤12	704	50		
>12	715	50	1.2	(0.8–1.6)
Distance between home and pig houses				
≤20 m	682	50		
>20 m	686	50	1.3	(1.0–1.7)
Ventilation				
Mechanical	1,220	96		
Natural	44	4	2.9	(1.3–6.8)
Location of air outlet				
Roof	508	41	1.2	(0.7–2.0)
Side	612	50	1.0	(0.6–1.7)
Pit	113	9		
Double pit				
Present	264	20		
Absent	1,050	80	1.0	(0.7–1.4)
Placement of units				
With full-length corridor	1,019	80		
Without full-length corridor	261	20	1.1	(0.8–1.6)
Floor				
Slatted or half-slatted	1,169	91		
Other types	119	9	1.7	(1.1–2.7)
Slat material				
Metal or synthetic	642	50		
Concrete	630	50	1.1	(0.8–1.4)
Feeding system				
By hand	1,086	84		
Mechanical	208	16	1.5	(1.0–2.1)
Wet feeding	272	21		
Dry feeding	1,022	79	0.9	(0.7–1.3)
Use of bedding				
None	607	50		
Sawdust	401	33	1.4	(1.0–1.9)
Wood-shavings	160	13	2.2	(1.5–3.4)
Straw	43	4	1.7	(0.8–3.7)
Cleaning of units				
After each finishing round	1,264	92		
Not after each round	112	8	1.2	(0.7–1.9)
Use of disinfectants when cleaning				
Never	212	16		
Always or sometimes	1,154	84	1.6	(1.1–2.3)

[a]Based on 1,432 farmers.
[b]Based on 1,048 farmers.

square and two-tailed t-tests. Those characteristics with significant associations ($p < 0.10$) were then included in a logistic regression model. Characteristics that failed to maintain a significant association with symptoms were eliminated from the models. The factors that contributed significantly are expressed as prevalence odds ratios (POR) with 95% confidence intervals (CI) [Checkoway et al., 1989].

Differences in values of lung function between farmers with and without symptoms were analyzed with t-tests. Associations between farm characteristics and lung function were tested by using multiple linear regression. The same farm characteristics were tested for the chronic symptoms. In this analysis, percentage of reference value of FEV_1 was used as the measure of outcome.

RESULTS

Response

There were 1,504 completed questionnaires returned before the closing date, a response of 62%. Women (n = 57) and respondents who gave no information on gender (n = 10) were excluded before analysis.

Mean age of the 1,432 male swine farmers was 38.5 years (SD 10.4). The age distribution was consistent with that of the population from which the sample was drawn. Mean duration of work in swine farming was 14.9 years (SD 8.8). Of the respondents, 29.6% were current smokers and 30.7% were ex-smokers. A history of atopy during childhood was reported by 8.6% of the respondents. Farm-owners comprised 96.3% of the respondents; the others worked as family members (3.0%) or employees (0.7%). The median number of hours working in swine confinement per week was 46.

Symptoms and Lung Function

As displayed in Table II, 32.9% of the swine confinement workers reported one or more chronic respiratory symptoms. Chronic respiratory symptoms were more prevalent among current smokers than among ex- and never-smokers (POR 2.9, 95% CI 2.1–4.1) and were more common among older farmers (POR 1.3 per 10 years, 95% CI 1.0–1.4) and among those with a history of childhood atopy (POR 2.7, 95% CI 1.7–4.4, corrected for age and smoking habits).

Farmers experiencing chronic respiratory symptoms had significantly lower mean lung-function values for all parameters than farmers without such symptoms (Table III). Farmers with chronic symptoms had mean lung functions lower than reference value for all parameters except FVC. Farmers without symptoms had lower than reference mean values for MEF50, MEF25, and MMEF only.

TABLE II. Prevalence of Chronic Respiratory Symptoms Among 1,432 Swine Confinement Farmers: The Netherlands, 1990

Symptom	Total (%)	Smokers (%)	Non-smokers (%)
Chronic cough	17.8	34.2	10.9
Chronic bronchitis[a]	13.8	20.9	10.5
Shortness of breath	7.5	10.4	6.3
Wheezing	17.1	24.6	14.1
Wheezing >1 week	6.5	9.9	5.1
Chest tightness (asthma)	5.3	6.3	5.0
One or more of these symptoms	32.9	47.4	26.8

[a]Defined as productive cough on most days of at least 3 months in each of the last 2 years.

Farm Characteristics

The personal and farm characteristics that were examined for any association with symptoms are summarized in Table I, together with their distribution among the farms of the participants.

The study group worked relatively large and modern farms. This is a direct result of the selection procedure (minimum number of pigs required), which was intended to evaluate farmers who spend all or most of their time in swine confinement farming. The median number of pigs per farm was 560. Most of the farms (80%) had units with a corridor running the full length of the building and almost all (96%) had mechanical ventilation.

Since farmers who had either direct or indirect (via corridor) mechanical ventilation systems installed experienced an almost identical symptoms prevalence, they were grouped together. Information was obtained on other aspects of the ventilation system, but this information did not allow reliable regrouping. "Other types" of floors (Table I) comprise cambered floors with an installed heating system and solid, concrete floors.

Associations

The results are presented in two ways. In Table I, the results are given for all the factors that were investigated. The risk estimate of each factor was adjusted for age and smoking habits. As various farm characteristics may be strongly intercorrelated, all of the factors relating to chronic symptoms were entered in a multivariate model. Results of analysis with all significant factors corrected for each other, as well as for age and smoking, are presented in Table IV. In this final model, prevalence of chronic respiratory symptoms was associated with having more than two pig houses, natural ventilation, floor types other than slatted or half-slatted, mechanical feeding, and the use of bedding and disinfectants. When associations between farm characteristics and individual symptoms were studied in more detail, use of disinfectants showed more pronounced associations with asthma-like symptoms than with symptoms corresponding to chronic obstructive pulmonary disease (COPD).

Separate analyses with cases identified as farmers having one or more respiratory symptoms immediately after work, and one or more symptoms 4–8 hr after work were carried out as well. Results of these were similar to the results presented in Table IV. The percentage of reference value of FEV_1 was significantly lower with increasing number of years worked in swine confinement farming (Table V). Lung function was better if farmers had a larger number

TABLE III. Lung Function of 398 Swine Confinement Farmers With and Without Chronic Respiratory Symptoms, Expressed as Percentage of Reference Values: The Netherlands, 1991*

	With symptoms	Without symptoms
FVC	106.0	110.1
FEV_1	98.8	105.5
MEF75	94.1	103.4
MEF50	87.5	98.2
MEF25	67.8	78.3
MMEF	79.5	89.8

*$p < 0.005$ for all parameters (t-test).

TABLE IV. Multivariate Associations Between Farm Characteristics and the Prevalence of One or More Chronic Respiratory Symptoms Among Swine Confinement Workers, Corrected for Age and Smoking: The Netherlands, 1990*

Characteristic	POR (95% CI)
Number of pig houses	
>2 vs. 1 or 2	1.5 (1.1–2.1)
Ventilation	
Natural vs. mechanical	2.6 (1.0–6.6)
Floor	
Other types vs. slatted or half-slatted	2.1 (1.2–3.6)
Feeding system	
Mechanical vs. by hand	1.4 (1.0–2.0)
Use of bedding	
Sawdust vs. none	1.4 (1.0–1.9)
Wood-shavings vs. none	2.2 (1.4–3.5)
Use of disinfectants	
Always or sometimes vs. never	1.7 (1.1–2.6)

*In final model n = 813.

TABLE V. Univariate Associations Between Farm Characteristics and Lung Function (% FEV_1 of Reference) of 398 Swine Confinement Farmers: The Netherlands, 1991

Characteristic	β	p	Effect in ml
Number of years worked in swine confinement (per 10)	−1.91	0.05	−51
Number of pigs (per 100)	0.23	0.03	8.5
Location of air outlet			
Pit vs. side or roof	−6.07	0.03	−248
Use of bedding			
Wood-shavings vs. sawdust or nothing	−3.53	0.10	−114

of pigs. This remained true when the analysis was done separately for pig breeders and for finishers. Lung function was worse for farmers with the air outlet of their ventilation system via the pit, as opposed to via the roof or side. There was a tendency toward lower lung function if farmers used wood-shavings for bedding, but due to small numbers this did not reach statistical significance. Non-significant relations were found for all other variables listed in Table I (not shown).

DISCUSSION

This study showed that swine confinement farmers in The Netherlands had an increased risk for respiratory morbidity if they have a large number of pig houses, natural ventilation, floor types other than slatted or half-slatted, mechanical feeding systems, and when they use wood-shavings and disinfectants.

One of the most interesting findings of our study was the association between use of bedding and respiratory symptoms, with the most pronounced effect found for wood-shavings. Use of bedding can lead to more dust and associated pollutants. An association of the use of bedding with respiratory morbidity is therefore plausible. Use of bedding has not yet been implicated as a contributory factor in the development of airway disease in swine confinement workers. However, there is evidence in the literature that wood-based contact litter is associated with high allergen concentration in the air [Gordon et al., 1992]. Wood-shavings are also implicated as a source of increased mould exposure and a cause of respiratory symptoms [Kolmodin-Hedman et al., 1987; Goldsmith and Sky 1988]. If other studies can affirm a causative role for use of bedding, this is a factor easily accessible for preventive measures.

No mention had previously been made of the role of disinfectants in the development of respiratory symptoms among swine farmers. In another part of our study [Preller et al., 1995b], duration of disinfection procedure and pressure used for spraying were found to have a direct relation with chronic symptoms and to be inversely related to baseline lung function. It can be claimed that the use of these chemicals can aggravate airway inflammation through irritation. Furthermore, it is known that chloramine-T is associated with bronchial reactions [Dijkman et al., 1981]. The need to frequently use disinfectants could equally well be correlated with farming practices that increase exposure to other causative factors. Either way, the promotion of farming practices that eliminate frequent use of disinfectants could be a way to prevent respiratory symptoms.

In our study symptoms tended to increase as farmers had larger numbers of pig houses. This might be an indication of an exposure-effect relationship, or it could reflect better hygienic conditions in modern farms with fewer, but larger pig houses. Zejda et al. [1993] suggested such an explanation for the inverse association they found between chest wheeze and number of pigs per barn. Likewise, we found a positive association between total number of pigs and lung function. This is supported by evidence from our studies that aspects of hygiene were associated with dust exposure [Preller et al., 1995a]. Another explanation could be that farmers with more pig houses are more frequently exposed to sudden changes of temperature, a factor that may contribute to chronic respiratory symptoms via bronchial hyperresponsiveness. As natural ventilation is probably less effective than mechanical ventilation in reducing levels of dust and gases in the air, this could explain its positive association with symptoms. This finding is in accordance with the negative association with lung function found by Bongers et al. [1987]. In the design of new confinement units, the use of natural ventilation should be discouraged. We also found an association between location of air outlet and lung function.

Fewer symptoms were found when farmers used slatted and half-slatted floor types. Poorer drainage of manure leading to higher levels of air pollutants could account for higher symptom prevalence in solid, concrete floors. Cambered floors, however, are slatted for about two-thirds of the surface, so the higher symptom prevalence for this type was unexpected. Furthermore, earlier we found cambered floors as such to be associated with lower exposure to endotoxins [Preller et al., 1995a].

One would expect wet mechanical feeding systems (requiring less personal attention by the farmer in the units) to be associated with a lower exposure, as found by Attwood et al. [1987], and therefore with lower symptom prevalence. However, we found no associations of this kind between feeding systems and symptom prevalence. An explanation could be, that we found wet feeding to be associated with higher exposure to endotoxins, yet with lower exposure to dust [Preller et al., 1995a]. Lung function was slightly and non-significantly lower for farmers with mechanical feeding systems. The only other study that reported an association between mechanical feeding systems and health effect [Bongers et al., 1987] also found lower lung functions if farmers used mechanical feeding.

In the literature we could find practically no studies in which attempts had been made to link specific characteristics of confinement units to respiratory symptoms, or indeed to any health-effect parameter. In the present study, an association was shown between chronic symptoms and number of hours worked as in Cormier et al. [1991], Willhelmsson et al. [1989], and Zejda et al. [1993], and between lung function and number of years worked. This supports an exposure-response relationship between work in swine confinement farming and health effects.

We used farm characteristics as representative for true exposure. These characteristics remain stable for some time. Both farms and farming methods are modernized from time to time, but these changes take a while. The description of farm characteristics by a questionnaire at a given point in time is, therefore, a good surrogate for exposure during recent years. Development of symptoms consistent with COPD or asthma is a matter of between weeks to a few years. Therefore, information collected by questionnaire describes the situation at the time when the measured effect on symptoms develops. This is less the case when lung function is considered: development of detectable lung function differences takes several years. A cross-sectional study cannot reliably collect information on farm characteristics over such a extended period of time. In our view, this explains the discrepancies between the survey and lung-function portions of the study.

Our findings are based on associations between health outcomes and farm characteristics as exposure surrogates. Conclusions are limited by the fact that we can only partly support our findings by data of measured exposure. Baseline lung function was associated with ammonia exposure as reported by Donham et al. [1995] and with endotoxin exposure in asymptomatic farmers only [Preller et al., 1995b]. Personal exposure to dust, endotoxins, and ammonia measured in winter and summer was not related to chronic symptoms. The strong associations with characteristics in this study rather than with measured exposures are partly explained by larger numbers of participants in this part of the study and partly because measured exposures turned out to be homogeneous for this group of swine confinement farmers [Preller et al., 1995a].

A potential problem in prevalence studies such as the present one is health-selective turnover of workers. A strong "healthy worker effect" is not likely in our population of swine farm owners: the heavy investments both in money and skill in their operations force them to continue in swine farming until compelling health problems arise. The development of chronic bronchitis will seldom be sufficiently compelling before retirement age.

The classification of farmers on the basis of contact with a characteristic in the type of operation in which he spent most of his time, undoubtedly led to some misclassification. This misclassification was non-differential as it was not determined by the effect of explanatory variables. Therefore, the misclassification was the same or almost the same in cases and non-cases alike. In the case of non-differential misclassification, associations tend to be biased toward 1, leading to an underestimation of effect.

This study was initiated to identify preventable risk indicators. Estimation of precise exposure-response relationships for the characteristics found is not yet feasible. Therefore, during analysis, preference was given to an approach which produced maximum achievable contrast between cases and referents. Thus, farmers who showed no respiratory symptoms at all were chosen as referents. An alternative approach would be to take as referents all those without chronic symptoms. Roughly balancing equations were obtained using the latter method: associations between characteristics and symptoms tended to be slightly weaker, but generally, the same variables remained significant in the final model.

In conclusion, based on our findings, we recommend that the use of wood-shavings as bedding material and frequent use of disinfectants in swine confinement farming should be discontinued and the use of mechanical ventilation should be encouraged.

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